

Lattice Gauge Theory

Michael Creutz

Lattice gauge theory has many successes

- Confinement Quark C_{onf}ining D_{ynamics}
- Hadronic spectrum
- Verification of chiral symmetry breaking $m_\pi^2 \ll m_\rho^2$
- Deconfinement at high temperature $T_c \sim 170$ Mev
- Matrix elements to test standard model (K decays, etc.)

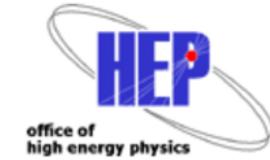
Lattice gauge theory has much future potential

Experiments need lattice results for interpretation

- plasma at BNL; $g - 2$
- structure functions at JLAB
- weak decays at FNAL, SLAC, BNL, CLEO

Theory errors often dominate

TERASCALE COMPUTING ESSENTIAL TO PROGRESS



BNL HET group pioneered numerical lattice gauge theory

Current HET group members concentrating on the lattice

Michael Creutz

Amarjit Soni

Plus two supported by SciDAC (I'm the BNL PI)

Chulwoo Jung

Konstantin Petrov → Enno Scholz

Shrinking HET group compensated by major growth of other groups

- New lattice gauge group associated with nuclear theory

Frithjof Karsch (group leader)

Saumen Datta

Peter Petreczky

Christian Schmidt

Takashi Umeda

Felix Zantow

- RIKEN and affiliates

Sinya Aoki

Tom Blum

Chris Dawson

Taku Izubuchi

Shigemi Ohta

Shoichi Sasaki

Takumi Doi

Koichi Hashimoto

Takeshi Yamazaki

- Close collaboration with Columbia
 - Norman Christ
 - Robert Mawhinney
 - many students
- APS
 - Urs Heller
- Increasing collaboration with UKQCD (Edinburgh)

BNL is a world class place for lattice people!



Recent HET lattice publications (2005- MC, Jung, Petrov, Soni, Scholz)

Y. Aoki et al. The kaon b-parameter from quenched domain-wall qcd. 2005.

David Atwood, Shaouly Bar-Shalom, and Amarjit Soni. Neutrino masses, mixing and leptogenesis in a two higgs doublet model for the third generation. *Phys. Lett.*, B635:112--117, 2006.

C. Aubin et al. Systematic effects of the quenched approximation on the strong penguin contribution to epsilon'/epsilon. 2006.

Shaouly Bar-Shalom, David Atwood, and Amarjit Soni. 'seesawing' away the hierarchy problem. *PoS*, HEP2005:358, 2006.

F. Berruto, T. Blum, K. Orginos, and A. Soni. Calculation of the neutron electric dipole moment with two dynamical flavors of domain wall fermions. *Phys. Rev.*, D73:054509, 2006.

F. Berruto, Tom Blum, K. Orginos, and A. Soni. Neutron electric dipole

moment with two flavors of domain wall fermions. *PoS*, LAT2005:010, 2005.

G. Cavoto et al. Angles from b decays with charm. 2006.

Hai-Yang Cheng, Chun-Khiang Chua, and Amarjit Soni. Effects of final-state interactions on mixing-induced cp violation in penguin-dominated b decays. *Phys. Rev.*, D72:014006, 2005.

M. Creutz. The invariant measure for su(n). *AIP Conf. Proc.*, 756:466-466, 2005.

Michael Creutz. Fun with dirac eigenvalues. 2005.

Michael Creutz. Hidden symmetries in two dimensional field theory. 2005.

Michael Creutz. Isospin breaking and the chiral condensate. *PoS*, LAT2005:119, 2005.

Michael Creutz. Flavor extrapolations and staggered fermions. 2006.

C. Dawson, T. Izubuchi, T. Kaneko, S. Sasaki, and A. Soni. K(I3)

form factor with two-flavors of dynamical domain-wall quarks. *PoS*, LAT2005:337, 2005.

F. Farchioni et al. Lattice spacing dependence of the first order phase transition for dynamical twisted mass fermions. *Phys. Lett.*, B624:324--333, 2005.

F. Farchioni et al. Numerical simulations with two flavours of twisted-mass wilson quarks and dbw2 gauge action. 2005.

(ed.) Fujii, K., (ed.) Miller, D. J., and (ed.) Soni, A. Linear collider physics in the new millennium. Singapore, Singapore: World Scientific (2005) 499 p.

A. Jakovac, P. Petreczky, Konstantin Petrov, and A. Velytsky. On charmonia survival above deconfinement. 2006.

Chulwoo Jung. Thermodynamics using p4-improved staggered fermion action on qcdoc. *PoS*, LAT2005:150, 2005.

Ken Kiers, Michael Assis, David Simons, Alexey A. Petrov, and Amarjit Soni. Neutrinos in a left-right model with a horizontal symmetry. *Phys.*

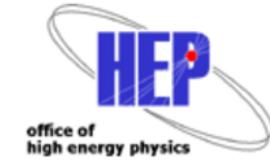
Konstantin Petrov. Quarkonium correlators and spectral functions at zero and finite temperature from fermilab action. *Eur. Phys. J.*, C43:67-70, 2005.

L. Scorzato et al. $N(f) = 2$ lattice qcd and chiral perturbation theory. *Nucl. Phys. Proc. Suppl.*, 153:283--290, 2006.

A. Soni and J. Zupan. Semi-inclusive hadronic b decays as null tests of the standard model. 2005.

Amarjit Soni. Cp violation highlights: Circa 2005. 2005.

Amarjit Soni and Denis A. Suprun. Determination of gamma from charmless $b^+ \rightarrow m^0 m^+$ decays using u-spin. *Phys. Lett.*, B635:330, 2006.



The Lattice SciDAC Project

SciDAC: Scientific Discovery through Advanced Computation

66 US lattice theorists; 9 member executive committee:

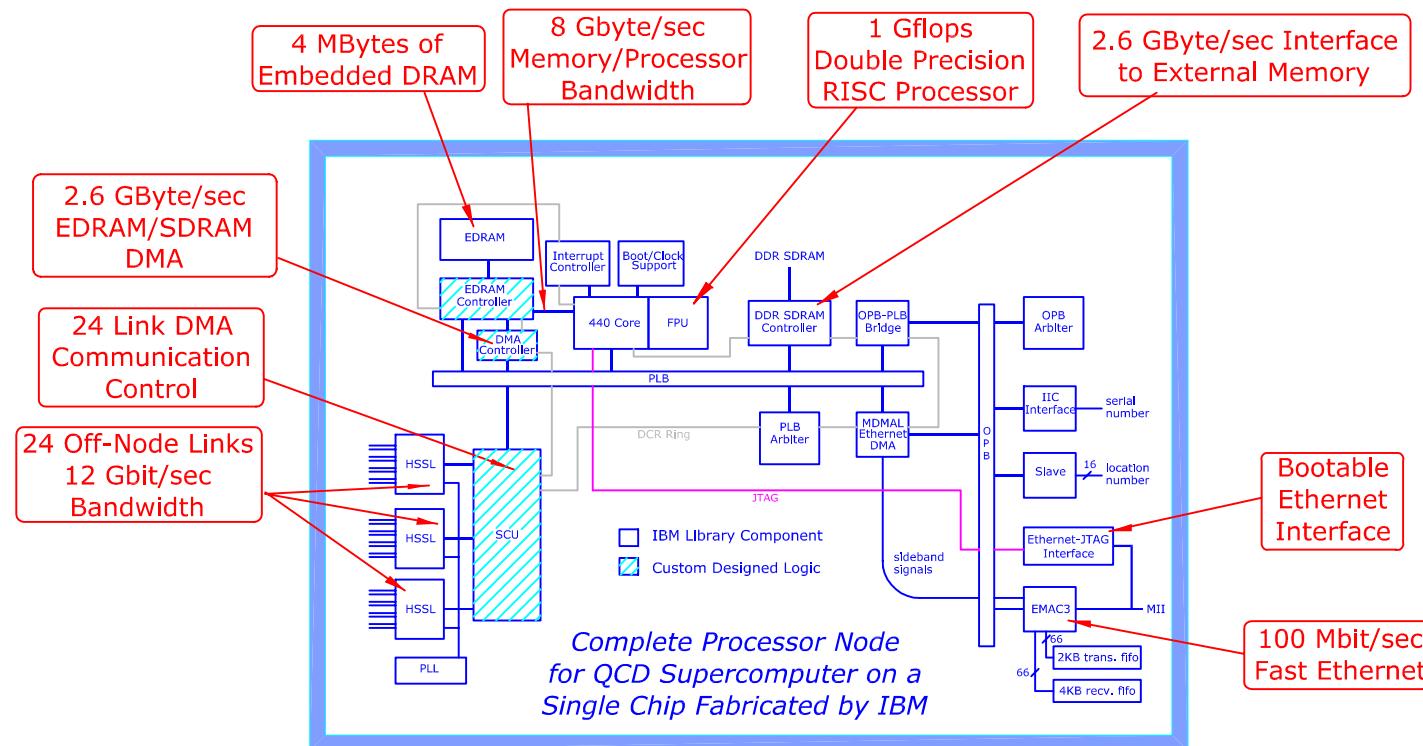
R. Brower, (Boston U.) N. Christ (Columbia U.), M. Creutz (BNL), P. Mackenzie (Fermilab), J. Negele (MIT), C. Rebbi (Boston U.), D. Richards (JLAB), S. Sharpe (U. Washington), R. Sugar (UCSB)

Two prong approach

- QCDOC at BNL
- commodity clusters at Fermi Lab and Jefferson Lab
- $\sim 3 \times 10$ Teraflops distributed computing facility

QCDOC places entire node on a single custom chip

QCDOC ASIC DESIGN



Mission-critical, custom logic (hatched) for high-performance memory access and fast, low-latency off-node communications is combined with standards-based, highly integrated commercial library components.

QCDOC

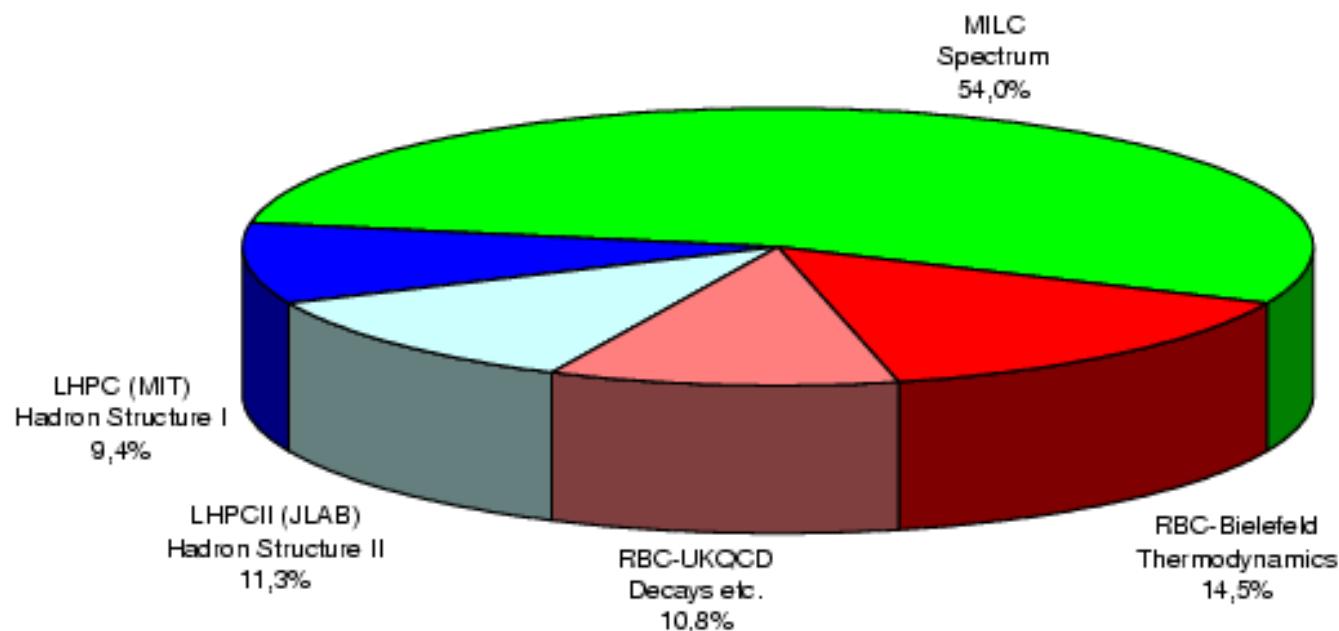
- next generation after QCDSP
- designed by Columbia University with IBM
- on design path to IBM Blue Gene
- Power PC nodes connected in a 6 dimensional torus
- processor/memory/communication on a single chip

UKQCD, RIKEN, DOE machines all running production

- 12K+ processors each
- Columbia Physics System Dirac inverter $\sim 40\%$ of peak
- MILC code $\sim 20\%$ of peak



Allocation on DOE-QCDOC



Needs and desires

Most lattice effort now outside HET group

- are we done shrinking?
- support for visitors and travel essential for vitality
- we need at least one lattice postdoc in our group

Security (not just a BNL problem)

- one month to get non-US visitors on site; including SUNY students!
(details on specific cases available)
- even US visitors have to hassle
- crippling spontaneous exploitation of new ideas
- many foreigners refuse to come to the US